

Development of rehabilitation engineering over the years: As I see it

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INTRODUCTION

The descriptive words “Rehabilitation Engineering” were not used widely, if at all, in America until the late 1960s and early 1970s, and then mostly by persons who had first been involved with prosthetics research and development immediately after World War II. Rehabilitation engineering in America owes its birth to the federal agencies that fostered its development after they had been so successful in supporting programs of research, education, and development in limb prosthetics and orthotics (initially for veterans) during the period from 1945 to 1970. But before its more or less formal birth in America around 1970, examples of engineering activities in the rehabilitation field can be cited through much of recorded history.

BRIEF HISTORY (1500 B.C.E. TO JANUARY 30, 1945)

Forms of technology for persons with disability can be traced back at least 3500 years to the Egyptian civilization. An Egyptian stele showing a woman physician presenting her disabled male patient to the god Isis may be viewed in the Carlsberg Sculpture Museum in Copenhagen. The patient depicted had had polio, which resulted in a weakened leg and resultant drop foot. He used a long pole as a mobility aid. Surprisingly, this same mobility aid is still in use in a number of places in the world.

Dr. René Baumgartner took the photograph shown in **Figure 1** on a trip to Africa in 1993.

It shows a person with the same form of disability and the same kind of assistive aid as used more than three thousand years earlier. In one way the photograph may indicate a lack of progress in rehabilitation aids. Looked at another way, the pole is a simple and ingenious mobility aid when only one leg is impaired and when the arms are capable of holding up the body. This aid could be praised for its durability, practicality, effectiveness, and availability. The principle is used in high-income as well as in low-income countries. It is not uncommon in America to see persons with high-level unilateral leg amputations gain good mobility through use of an axillary crutch on the amputated side. Similarly, traditional walking canes (sticks) have a long and distinguished history of effectiveness in assisting persons who have mobility disorders.

Paintings of Brueghel, the Elder, many of which may be seen in the Kunsthistorische Museum in Vienna, contain a number of images of persons of the 16th century with disability (for example, limb loss, polio, and cerebral palsy) using crude crutches, sticks, and other simple mobility aids. Through the ages the development of rehabilitation technologies have mostly come about as a result of disease, injury, and warfare. However, the most significant technical milestones seem to have been connected with wars. In fact wars have been veritable watersheds for the technical development of assistive devices for surviving combatants. One of the best-known and



Figure 1.

This photograph, taken by René Baumgartner, MD, in Tanzania in 1993, shows a man with an impairment (paralysis of left leg from polio) who uses a simple assistive aid for walking. The aid is similar to one used in Egypt around 1500 B.C.E. as recorded on an ancient Egyptian stele that is now in the Carlsberg Sculpture Museum in Copenhagen.

effective artificial hands ever made (Circa 1500 C.E.) belonged to the noble German Knight, Goetz von Berlichingen, whom Goethe immortalized in the play, *The Iron Hand*.

The days of knighthood were ending in the 1500s, but the knights' armor makers had developed many of the skills needed in the field of prosthetics and orthotics. Ambroise Paré (1510–1590), a French military surgeon of that period, introduced the ligature. He was appar-

ently the first surgeon to establish guidelines for amputation sites and to follow up his patients' prosthetic fittings, which were fabricated in conjunction with an armorer, "le petit Lorrain." Paré introduced a scientific approach to amputation surgery and is regarded as the founder of modern principles of amputation. As such, we could regard him as the father of the prosthetics field and hence a possible candidate to be the father of rehabilitation engineering.

From the Napoleonic Wars, today's rehabilitation teams still prescribe "Nelson's Knife" (a rocker knife with fork tines at the end) to assist persons with only one functional arm to cut and spear meat just as it did for Lord Nelson. Lord Uxbridge, Wellington's cavalry officer lost his leg above the knee in the battle of Waterloo. The artificial leg provided for him, designed in 1800, became known as the Anglesea leg after Uxbridge became the Marquis of Anglesea. This above-the-knee prosthesis was designed so that the foot would automatically rotate so as to move the toe away from the walking surface as the knee bends during the swing phase of the leg. This helped the leg to clear the surface. The leg was widely used, first in the British Isles, and subsequently in modified form in America during and after the Civil War. The principle of operation continues in use today in the Hydracadence® prosthesis.

America's Civil War resulted in many limb amputations. There were 30,000 amputations on the Union side alone. This war changed the landscape of prosthetics service in America because many new prosthetics facilities were formed to take care of the casualties. Notable firms were those of James E. Hanger, a confederate soldier who lost a limb early in the war, and A.A. Marks, owner of a private company in New York City, who is well known because of his book, *A Treatise on Artificial Limbs*, published in 1901. The "hard rubber" foot, a forerunner of the SACH foot, was described in this book.

Except for organization of the Association of Limb Manufacturers in 1917, it appears that little was done nationally in the United States concerning prosthetics practice after World War I. However, important knowledge was being gleaned from the Canadians, British, French, and Germans about the care of soldiers with amputations. In particular the idea of collaboration between the limb makers and the surgeons started to gain acceptance at this time. The British established the Roehampton Amputation Center in 1915, one of the first amputation centers, and it had impact on American care

of amputees. Physicians such as Philip D. Wilson from America were sent to Europe after World War I to study amputation methods and fitting concepts. One of these trips resulted in a document entitled, "Lessons from the Enemy." There was much to learn from both ally and enemy. German methods in prosthetics, orthotics, and work aids at that time are well documented in the classic volumes of *Erzatzglieder und Arbeitshilfen* (Replacement Limbs and Work Aids) published in 1919. It clearly may be considered one of the first major publications in the field of rehabilitation engineering. Many ideas presented in this vintage publication remain valid today.

Germany may have been the first to develop rehabilitation teams to serve the needs of persons with disability. Ferdinand Sauerbruch, the famous German surgeon pictured in **Figure 2**, worked together with engineers and



Figure 2.

Photograph of Ferdinand Sauerbruch, MD, one of the first physicians to work with an engineer to design an artificial arm. Sauerbruch developed the "team" approach during his work on tunnel cineplasty for direct muscular control of artificial hands and arms.

physiologists in Zürich around 1915–16. At that time Sauerbruch engaged Aurel Stodola to assist with prosthesis development. Stodola, a highly regarded professor of Mechanics at the Polytechnical Institute of Zürich was a world expert on steam turbine design. This engagement is surely one of the first documented examples of a surgeon and engineer merging efforts. An advanced, mechanically driven prosthesis, controlled by muscle tunnel cineplasties, was developed. After their success, Sauerbruch said, "Henceforth, surgeon, physiologist, and technician (prosthetist/engineer) will have to work together." (See *Literary Digest*, August 26, 1916, page 453.) In Berlin the team consisted of Sauerbruch, the surgeon, Konrad Biesalski, MD, the physician who developed the physical therapy methods necessary for tunnel cineplasty's success, and Max Biedermann, the prosthetist who interfaced the prostheses with the cineplasty controls. Ferdinand Sauerbruch is a legitimate candidate to be considered the founding father of rehabilitation engineering.

In Russia, Nikolai Bernstein and his associates in the laboratory of Physiology and Pathology of Movements at the Moscow Research Institute of Prosthetic Appliances took a scientific motor control approach to prosthetics. Bernstein made many contributions to the field and his book, *The Coordination and Regulation of Movement*, is an important collection of some of his publications. They are valuable particularly for their theoretical and scientific contributions to the field.

In America, Paul B. Magnuson, MD, was active as early as 1910 in Chicago as a bone and joint and general surgeon and was already committed to the concepts of medical research and vocational rehabilitation. He fostered development of the new field of Physical Therapy at Wesley Memorial Hospital in Chicago and was the first to academically recognize the field of Physical Medicine and Rehabilitation. At the Northwestern University Medical School, he induced Dr. Stanley Coulter, an associate, to set up the first Physical Medicine Department in the country. Coulter was an early leader in physical medicine and became the first Professor of Physical Medicine at Northwestern. Later, Magnuson's top positions within the Veterans Administration from 1945 to 1951 allowed him great freedom of action in affecting good medical and rehabilitative care for American veterans. As Dr. Henry Betts, former Medical Director of the Rehabilitation Institute of Chicago has noted, Magnuson was a friend of Dr. Howard Rusk, and pursued the philosophies of rehabilitation in the VA that Rusk had developed in the military hospitals.

Magnuson's commitment to research, instilled during his medical school days when he investigated bone lengthening, led him to approve VA support of the national prosthetics research program that developed through the National Research Council following 1945. Magnuson also founded the Rehabilitation Institute of Chicago, where prosthetics research began in 1957 under the direction of orthopaedic surgeon Clinton Compere, engineer Colin McLaurin, and prosthetist Fred Hampton. A rehabilitation engineering center (REC) was formed there in 1972 with a research agenda encompassing studies of endoprostheses of the knee and hip, and the development of technical equipment to assist persons with significant disabilities such as quadriplegia. Today, the RERC at Northwestern concentrates on external prosthetics and orthotics. Dr. Magnuson died in 1968 but Dr. Compere often related that Magnuson would have greatly enjoyed seeing the work done on powered prostheses for persons with limb loss. Although not commonly recognized in some circles, Dr. Magnuson had a profound impact on technology in rehabilitation and could rightfully be viewed as a father of the field.

Looking back, it can be observed that in the early decades of the 20th century, the work of people like Sauerbruch, Bernstein, and Magnuson represented a nascent interest in various aspects of what we now call rehabilitation engineering. Rehabilitation engineering was undoubtedly exhibiting birth pangs in many other locations and in many other ways during this same period of time. We might say that, like the then-new field of aeronautics, the new field of rehabilitation engineering was beginning to take flight.

Along with the activities of Dr. Magnuson, the Chicago area witnessed other rehabilitation engineering activities during the 1920s. The daughter of Mr. Henry Pope had had polio and needed better orthotic bracing components. Pope, who owned the Paramount Textile Machinery Co. in Kankakee, Illinois (which made hosiery), asked John Klenzak, an outstanding engineer with the company, to design a new bracing system based on lightweight aircraft construction techniques. This endeavor formed the beginning of the Pope Brace Co. In 1928 Carl Hubbard, another one of Pope's engineers, designed the Hubbard Tank, which is often used in hydrotherapy. Klenzak and Hubbard might be considered two of America's first rehabilitation engineers. Henry Pope, Franklin D. Roosevelt, and Barnard Baruch used their friendship, influence, contacts, and money to facilitate growth of rehabilitation facilities in Warm

Springs, Georgia. This location, along with Rancho Los Amigos Hospital in Downey, California, turned out to be particularly important locations for the growth of the field of orthotics in the United States.

FEDERAL FUNDING FOR PROSTHETICS RESEARCH AND DEVELOPMENT

The birth of federal funding for prosthetics in America—and ultimately for rehabilitation engineering—transpired at a meeting in Thorne Hall, January 30, 31, and February 1, 1945, near the shore of Lake Michigan, on the Chicago campus of Northwestern University (see **Figure 3**). The Battle of the Bulge was raging in Europe at the time.

The meeting was held, to some extent, in response to a clamor for better artificial limbs from veterans who had lost limbs in the war effort. Surgeon General Kirk asked the National Research Council (NRC) to convene a meeting to determine what should be done about the mounting need for improved artificial limbs. The location for the event probably came about because Chicago was the hub of the nation's railroad system and because Dr. Magnuson, Chairman of Bone and Joint Surgery at Northwestern University, was well known in Washington, DC for his work in prosthetics and rehabilitation. Magnuson also had served as a Major in the Surgeon General's office during World War I and as a civilian consultant to the Surgeon General from 1941 through 1946. The meeting was attended by about 80 persons, including a few from Canada and the Soviet Union. Attendees were mostly physicians, prosthetists, engineers from the aircraft industry, administrators, and physical therapists. Dr. Magnuson and Paul Klopsteg, PhD, ScD, who was then Director of Research for Northwestern's Technological Institute, were prominent at the meeting. Later Klopsteg and Phillip D. Wilson would combine efforts as editors for America's classic book in prosthetics, *Human Limbs and Their Substitutes* (1954).

The aim of the Chicago meeting was to recommend the best artificial limbs for Army veterans. The result was that the best limbs were considered none too good and that more work needed to be done in order to improve the art. The decision was made to form the Committee on Prosthetics Devices within the NRC to direct the effort to achieve better prostheses. The NRC venue was key to the success of the Committee because the NRC imprimatur provided the Committee and its successors with national prominence, recognition, and



Figure 3.

Thorne Hall, on the Chicago campus of Northwestern University, is shown in this photograph. It can be viewed as the birthplace of American prosthetics programs. A meeting held here in 1945 led to formation of the Committee on Prosthetics Research and Development (CPRD) of the National Research Council (NAS/NRC) from which the Rehabilitation Engineering initiative later was launched.

credibility for the next 30 years. The Committee later became the Advisory Committee on Artificial Limbs and subsequently the Prosthetics Research Board. Ultimately it became the Committee on Prosthetics Research and Development (CPRD), first directed effectively by Brig. Gen. F.S. Strong, Jr. and later by A. Bennett Wilson, Jr., who was assisted by Hector Kay.

I am most grateful to CPRD for the assistance it provided me when I was new to the field of prosthetics. In 1968, just two years after I was hired by Dr. Clinton Compere, CPRD enabled me to travel to Belgrade, Yugoslavia, with Mr. Hector Kay, Associate Director of CPRD, to evaluate the Belgrade Hand. This trip also enabled me to meet many rehabilitation engineering investigators in Yugoslavia (e.g. Lojze Vodovnik and Alojz Kralj). In 1969 I was elected a member of CPRD and became Chair of the Upper-Extremity Prosthetics

Panel in 1971. In 1972, CPRD enabled Mr. John Billock and me to make a month-long tour of European laboratories that were working on upper-limb prostheses. Upper-limb prosthetics research was particularly active at that time because of birth-related limb loss caused by use of Thalidomide.

It was on that trip that we met David C. Simpson of the University of Edinburgh. He introduced us to the control concept of Extended Physiological Proprioception (E.P.P), a control theory that we still apply widely and which explains so much about what works and what doesn't in the fields of prosthetics and orthotics. E.P.P. has to do with the body's ability to use tools effortlessly and naturally if they can be used as direct extensions of the body. A classical example is the tennis racquet which even a modest player makes a natural extension of the body and uses without thinking about it. (Many examples

from rehabilitation are brought to mind, the long cane used as a walking aid by persons with blindness, the standard cane, below-knee and below-elbow prostheses, mouthsticks, and so forth.) Simpson designed prostheses on this principle, and this enabled persons to use them naturally and without too much mental effort.

We met Dr. A. Bottomley (London), Dr. G.G. Kuhn (Münster), Dr. E. Marquardt (Heidelberg), Dr. H. Schimdl (Bologna), and many others. We visited the manufacturing facilities of Otto Bock. The trip gave us an immediate update on the state-of-the-art of prosthetics in Europe, provided us with a sense of history of the field, established lifelong relationships that benefited our careers, and immersed us in a wealth of knowledge, ideas, and concepts.

FEDERAL FUNDING FOR REHABILITATION ENGINEERING

In the late 1960s, A. Bennett Wilson, Jr., Director of CPRD; Joseph Traub of the Rehabilitation Services Administration; Anthony Staros of VA; and others (engineers Colin McLaurin and James Reswick, for example) promoted the concept of Rehabilitation Engineering Research Centers as an enlargement of the very successful prosthetics programs. McLaurin and Reswick were rehabilitation engineering role models for me and for many others entering the field. Any of these persons could be considered as originators of the generalized rehabilitation engineering movement in the United States—perhaps A. Bennett Wilson, Jr., most of all. Nevertheless, the program could not have been consummated without the background support (political and otherwise) of surgeons and physicians such as William Berenberg of Boston, Clinton Compere of Chicago, Vernon Nickel of Los Angeles, George T. Aitken of Grand Rapids, William Spencer of Houston, Richard Herman of Philadelphia, and many others. It was a team effort. Some members of the group are shown in **Figure 4**.

In general, CPRD, using funds from the federal agencies involved, coordinated the national research effort in prosthetics, held meetings to access research and development progress and needs, evaluated products and techniques, published documents, reviewed research proposals, and promoted education. It was logical for this committee to suggest expanding the scope of its interest and to give birth to rehabilitation engineering, a whole new area for exploration. CPRD took rehabilitation engineering beyond prosthetics and orthotics and in

the process profoundly influenced what persons with disability could expect from modern technology.

CPRD was action orientated. On the other hand the NRC was primarily an advisory group, and this difference in organizational function led to conflict between NRC and CPRD. In the mid 1970s, this conflict of operating styles resulted in CPRD losing its position within the NRC, which had been its “Alma Mater” for more than 30 years. After the demise of CPRD, around 1976, the agencies involved continued with their programs in rehabilitation engineering but without the same coordination or sense of mutual cooperation that had been previously evident. It is possible that remnants of CPRD function might develop through the Interagency Committee on Disability Research (ICDR), which now appears to have significant funding to make it effective.

SOME THINGS I HAVE LEARNED

I have spent 36 years in prosthetics research, 15 years involved in the development of assistive equipment for persons with significant disabilities, and approximately 10 years in orthotics research. I thank all the people I have worked with, many of whom have gone on to successful careers in research and development, education, clinical care, manufacturing, sales, and other fields of endeavor. At Northwestern University I am particularly indebted to Dr. Clinton L. Compere, who brought me into the field of prosthetics; Edward C. Grahn, BSME, a colleague at Northwestern who has been in the field longer than I; and Rosemary “Bonnie” Collard who has kept me more or less on schedule and out of fiscal troubles for the last 27 years. What I have learned is that rehabilitation engineering must be a team effort in order to be effective. I have also learned the importance of administrative assistants who enabled me to spend most of my time on scientific and technological developments.

I have learned that a rehabilitation engineering research center needs to be located where the investigators and staff of the center interact daily with consumers/clients related to the research effort. Researchers also need to work together with the families of consumers/clients, with the providers of their rehabilitation technology or assistive equipment, and with their physicians and medical care providers, if appropriate. I have learned that rehabilitation engineering research cannot be an “ivory tower” activity. The investigators and staff of the research center need to meet persons



Figure 4.

Montage of photos, taken from the author's albums, shows some of the individuals who greatly contributed to early activities that initially influenced prosthetics and orthotics so profoundly and which later had great impact on rehabilitation engineering. [Top Left] Clinton L. Compere, MD (circa 1980), Chicago orthopaedic surgeon, founder of prosthetics research and prosthetics education at Northwestern University. [Top Center] The author, in darker suit, with Hector W. Kay in Yugoslavia during 1968. Kay was Assistant Executive Director of the Committee on Research and Development (CPRD) of NAS/NRC and founder of the Association of Children's Prosthetics/Orthotics Clinics. [Top Right] Paul B. Magnuson, MD (circa 1956), Chicago surgeon, architect of the VA Medical System after WWII, Chief Medical Director of VA (1948–51) and founder of the Rehabilitation Institute of Chicago. [Lower Right] The author, in center (circa 1985), is flanked on the viewer's right by A. Bennett Wilson, Jr., former Executive Director of CPRD, who perhaps more than any other person promoted the birth of Rehabilitation Engineering in the USA and by Colin McLaurin, DSc, former Chairman of CPRD and one of the foremost rehabilitation engineers on the continent. [Lower Left] Photo of Joseph E. Traub, CP (right), of the Social and Rehabilitation Service of DHEW (now NIDRR), who had a lot to do with development of rehabilitation engineering programs, talking with James B. Reswick, ScD, one of the foremost American rehabilitation engineers (circa 1989).

with disability (for example, limb loss) not only in formal venues such as clinics and examination rooms but also in informal places such as the dining room, cafeteria, elevators, and so on. The investigators also need to meet clients in their homes, at work, and in recreational environments.

In my work with prostheses I have learned that rarely is the first prosthesis prescription completely satisfactory. As clients use the prosthesis in daily activities they often discover new things they would like to do with it. Life is different than before they lost their limb(s). Consequently, artificial limb prescriptions change as time

and events go by. To some extent, prosthetic prescription is a lifetime activity of change and improvement. Just as prostheses periodically wear out, the prescription may become outdated. I have learned that successful prosthetics care involves replacement, alteration, and fine tuning throughout a user's lifetime, often as suggested by the user.

I have found through experience that there is a fundamental difference between rehabilitation engineering research and the clinical practice of rehabilitation engineering. A classical engineering education prepares students for engineering design, analysis, mechanism development, and for general technical and scientific competence. However, there is very little in traditional engineering education that prepares them for clinical rehabilitation, where the engineer works directly with clients much as a physician or therapist does. Engineers by nature are not brought up with the idea of making quick decisions about what assistive equipment to suggest in a prescription. Also, for the most part, as clinicians they can only recommend equipment that is commercially available. In addition, engineers are not used to keeping records of their activities in 15-minute increments. To some extent, clinical rehabilitation engineering was fostered by rehabilitation engineering research. Research created products to be used clinically and clinicians (for example, therapists) often sought out research engineers in their environment to make adaptations to existing equipment, and so on. In our program, I hired Mr. Ken Kozole originally to work in our NIDRR-supported engineering research center. Mr. Kozole had a degree in mechanical engineering and in occupational therapy. I believe that hybrid training of this kind can lead to very effective rehabilitation engineering efforts. In the late 1970s, after a few years in research, Mr. Kozole formed a clinical rehabilitation engineering department that still thrives within the Rehabilitation Institute of Chicago. We can see from this event, and there were many others like it, that rehabilitation engineering research has had wide impact that has gone well beyond just the engineering of assistive equipment or even investigations of how persons with disability may ameliorate problems with the assistance of engineering design or analysis.

I have learned that persons with disabilities should, if possible, be part of rehabilitation research teams. Bill Dellenback, whom we fitted with a myoelectric transradial prosthesis in 1972 was of invaluable assistance in our pre-hensor development research for more than 20 years. Mar-

garet Pfrommer (see **Figure 5**) worked in our laboratory for 25 years and participated positively in the development of wheelchair controllers, environmental controllers, communication aids, telephone controls, computer interface systems, home respiratory aids, and independent living. Others, like Thomas Shworles and Bill Jenks, were frequently in our center to assist with the design of assistive equipment. Margaret was active in RESNA and promoted rehabilitation technology locally, nationally, and internationally.

Today, scientists and engineers with disabilities are entering the prosthetic and orthotic field as researchers. In our center, Brian Buhe, who has bilateral limb loss above the knees, is working toward a PhD in Biomedical Engineering, with a speciality in prosthetics. Also, in a distinct change from the past, prosthetists and orthotists are beginning to take research degrees. In my laboratory alone we have two postdoctoral fellows who are qualified prosthetists/orthotists. They are Dr. Margrit Meier of Switzerland and Dr. Stefania Fatone, of Australia. In addition, Laura Miller, a graduate student with me, recently became a certified prosthetist (CP) and will soon receive the PhD degree in Biomedical Engineering. More students need to follow this direction of study. Their subsequent careers can be substantially strengthened through Research Career Development Awards (RCDA), which financially protect them as they launch their fledgling research agendas. Travel, although not of as much importance today as it was 30 years ago because of the communications revolution, also can greatly benefit young people entering the field. The Whitaker Foundation Graduate Fellowships in Biomedical Engineering are exemplary in this respect. My own career was assisted through an RCDA from NIH that I received in 1970 and by the travel opportunities provided by CPRD. Dr. James Reswick, one the founders of rehabilitation engineering (and author of an article in this volume), was a member of the team of site visitors that reviewed my NIH research proposal for an RCDA.

I have always contended that young graduate students and postdoctoral fellows with energy and new ideas are the lifeblood of a research center. In this light I note that the young students and fellows coming into our center for training over the last decade are among the best I have seen during my tenure at Northwestern University. Their superb academic qualifications, high personal standards, and technical know-how bode well for the future of the prosthetics and orthotics field.

Colin McLaurin taught me that rehabilitation engineering is much more than design and analysis. He

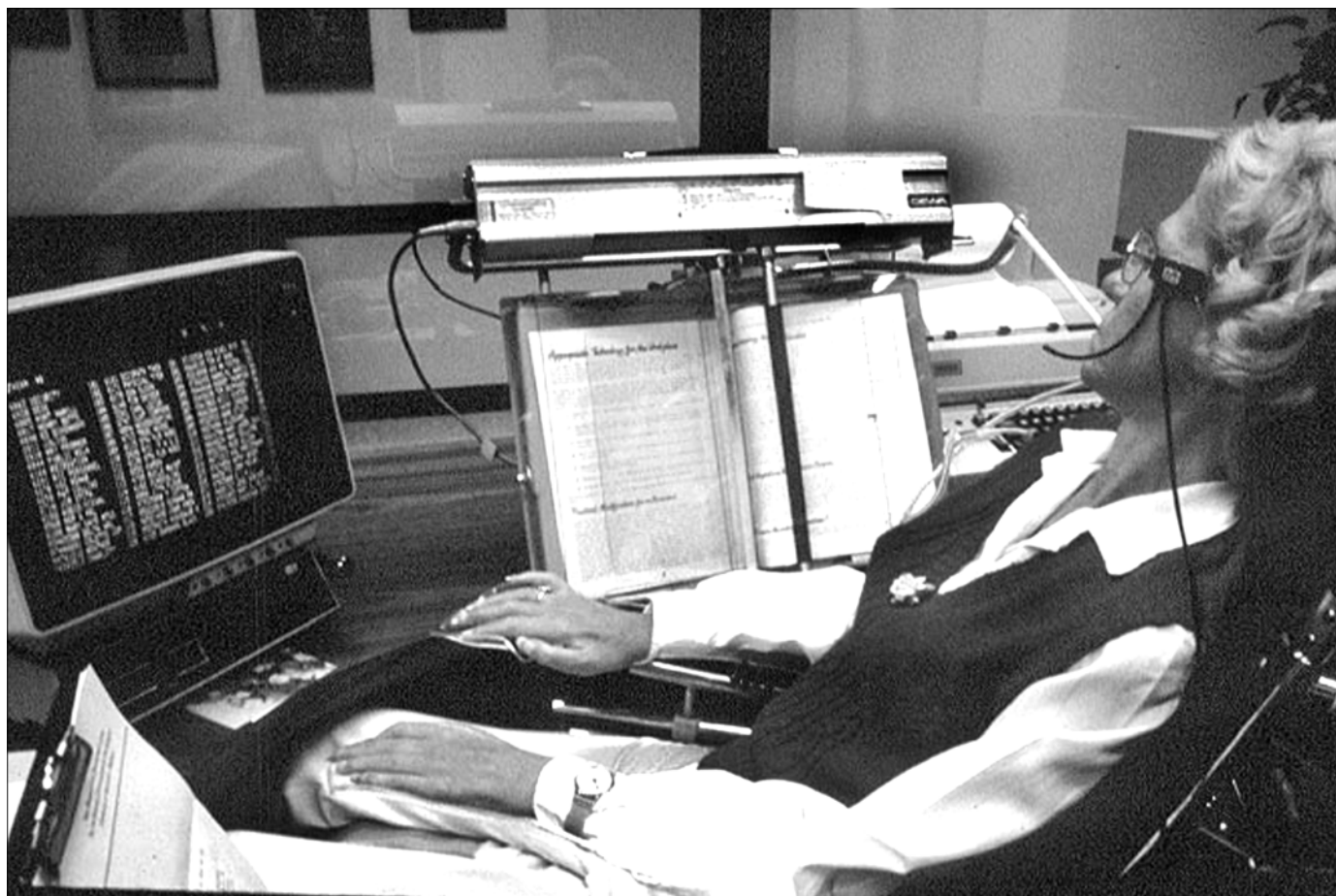


Figure 5.

Margaret Pfrommer, who had polio as a young woman, worked in the Northwestern University Rehabilitation Engineering Research Center (RERC) for 25 years, from 1973 until her death in 1998. In 1973 she was one of the first persons to use a computer dedicated to her work station. Although she had a high level of quadriplegia, she worked as a peer counselor, author, teacher, advocate for persons with disability, receptionist, research assistant, and champion of assistive technology. Margaret's life demonstrated independent living, assisted by technology at work, at home, and in life's various venues. In this picture she is shown using a sip and puff control straw to operate her wheelchair and also to control her office computer as a communication aid (text typing), as an environmental controller (e.g., page turner), and as a telephone exchange system. A number of these assistive devices were developed as a result of her presence in the laboratory at the Rehabilitation Institute of Chicago. Margaret presented the E&J Lecture at the 4th Annual Meeting of RESNA in Washington, DC, September 2, 1981.

thought engineers working in rehabilitation needed to systematize the knowledge of their field and develop guiding principles for the field through the use of science and engineering. The development of scientific principles to guide designs and evaluations is probably one of our field's greatest needs. We need to develop a healthy balance between theoretical and the more empirical approaches that have previously characterized most of the activity. Engineers need to develop the necessary knowledge to evaluate prostheses and all assistive devices. When a consumer, client, or caregiver contacts us, asking about assistive devices, we need to be able to present

them with the most authoritative and objective knowledge available. The consumer or caregiver may reject our viewpoint or suggestions, which is okay, but we should try to provide them the best information possible.

I have learned through experience that good engineering is vital to good products, but I also know that good technical design seldom is the sole determining factor in success of a device or product. We need only consider the VHS and Beta video recording systems to realize that the technical superiority of a product may not be all that makes a product successful. In rehabilitation engineering (as in other fields of engineering),

appearance, practical features, weight, cost, merchandizing, and other factors may be almost as important as engineering design excellence.

I was taught by Dr. Eugene Murphy of the VA that history is important to rehabilitation engineering and that history should be part of the systematic knowledge of the field. Sir Frances Bacon (1625) has said, "They that reverence too much old times are but a scorn to the new." The question of this quote is how much is "too much." A program needs a healthy reverence for history

to keep it grounded and moving in the right direction but not so much that the past dominates it.

Finally, I learned from pioneer Swedish rehabilitation engineers Fred Forchheimer and Bo Klasson that "The most advanced application of technology is not necessarily the same as the application of the most advanced technology." This quotation of Forchheimer, which has been popularized by Klasson, should be carefully considered by all engineers who work in the field of rehabilitation.